

SOME STUDIES ON THE INFLUENCE OF ENVIRONMENTAL FACTORS ON THE HATCHING OF THE EGGS OF *APHIS AVENÆ* FABRICIUS AND *APHIS POMI* DeGEER.*

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INTRODUCTION.

The eggs of *Aphis avenæ* Fabricius¹ and *Aphis pomi* DeGeer have two distinct layers in the egg shell (Figures 1 to 4). The outer layer, when the eggs are first deposited, is transparent, soft and glutinous, but it soon hardens upon exposure to weather conditions and becomes semi-transparent, toughened, dry and decidedly impervious to water. The inner layer is a soft, elastic, black membrane and decidedly pervious to water.

The outer layer usually splits (Figures 2 and 3) along the dorso-mesal line a number of days before the nymph emerges. The above structure and splitting of the outer layer is also characteristic of the eggs of other species of plant lice; a species of *Lachnus*, which deposits its eggs on the needles of whitepine, another aphid which deposits its eggs about the buds of weeping willow and at least one species of aphid which deposits its eggs in ant nests. I am indebted to Mr. J. L. King for furnishing me with eggs from an ant nest. The time and percentage of the splitting of the outer layer and the hatching is dependent upon environmental conditions, particularly temperature and moisture. The outer layer of the eggs of *A. avenæ* may start to split in February (February 10, 1919), while the splitting of the eggs of *A. pomi* usually does not start until March, (March 3, 1919). The eggs of *A. avenæ* usually hatch rapidly the last week in March and the eggs of *A. pomi* usually hatch rapidly somewhere between April 5 to 15th. The above observations are true for New Brunswick, N. J. For further information on the time and percentage of splitting and hatching, see Tables 4 and 5 and references.

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¹*Aphis avenæ* Fabricius is *Rhopalosiphum prunifoliae* Fitch according to A. C. Baker and W. F. Turner.

EVAPORATION.

The splitting of the outer coat of the egg and the percentage of hatch of the eggs of *A. avenæ* and *A. pomi* are influenced considerably by evaporating factors. These factors in a natural environment are moisture, temperature and wind velocity. This paper takes into consideration the response of the eggs to moisture and temperature.

The two layers of the egg are decidedly different in their pervious nature. To determine the relative permeability of the two layers of the eggs of *A. avenæ* a simple experiment was conducted in 1917; the outer semi-transparent tough layer was removed from fifteen normal eggs on April 5 and the skinned eggs were placed in a covered Syracuse watch glass. Fifteen normal eggs were placed in the same vessel. The skinned eggs shriveled completely inside of 24 hours and none hatched, while 6 of the 15 normal eggs hatched in 4 days. The above experiment was repeated with the eggs of *A. pomi* and the results were approximately the same. These experiments show that outer layer on the egg prevents evaporation under ordinary conditions, while the inner pigmented layer is of little use in preventing evaporation. If this is true then one may conclude that eggs with split outer coats are more susceptible to evaporating factors than normal eggs with whole outer layers.

MOISTURE.

The influence of moisture on the eggs of *A. avenæ* and *A. pomi* was determined by incubator experiments with controlled moistures and temperatures; by other experiments where the eggs were placed in moist chambers under ordinary conditions indoors and outdoors and by observing the percentage of splitting and hatching of the eggs of *A. avenæ* for four variable seasons, 1917 to 1920, and comparing these observations with the weather conditions for the respective years.

The controlled moisture and temperature experiments were conducted in 1917 and 1920 in the incubators and moisture control apparatus used by Dr. T. J. Headlee in his investigations on the bean weevil; the writer wishes to express his appreciation for the privilege of using this efficient equipment. The incubators were fitted with one to three moisture control systems. Each system (Figure 6) was composed of two air dryers, a

moisture generator, one or more air chambers and a pump. The moisture generators and the air chambers were located in the incubators and kept at a constant temperature; 80° F. in 1917 and 70-72° F. in 1920. The air was taken from the room and first passed through the two tubes of sulfuric acid (Specific Gravity 1.84), which removed all of the water. The dry air was then drawn through concentrated salt solutions and a constant amount of water was absorbed by the dry air. The moisture content of dry air after it passes through concentrated salt solutions varies with different salts, but the same salt always gives up a definite amount of moisture. This was determined for each salt a number of times and each test showed less than 0.5 per cent variation in the water present. The air goes from the moisture generator to the air chambers, where the numerous eggs were located on short twigs. Small twigs bearing numerous eggs were selected in order that the moisture arising from the freshly cut twigs would have as little influence as possible on the moisture content of the air. It is believed that the small amount of moisture arising from the twigs had very little effect; if the moisture in the twigs effects the air in the chambers the effect is of short duration, for it was noted that the twigs in the chambers having low moisture content dried and shriveled in two or three days, while the eggs usually required ten to fourteen days to hatch after they are placed in the air chambers. The air was drawn from the air chambers by a small pump, which was operated by flowing water.

Table 1 shows the influence of various constant percentages of moisture on the eggs of *A. avenæ* and *A. pomi*. The dates at the top of the columns indicate the day the experiments were started. The percentage of hatch varies with the moisture content; the greatest percentages of hatch occur in airs possessing a large amount of moisture, while low percentages of hatch occur in airs possessing small amounts of moisture and usually no hatch in dry air. Some of the eggs in the above experiments had split their outer coats when the experiments were started. In the dryer airs these eggs shriveled rapidly and failed to hatch.

In 1917 eggs of *A. pomi* were placed in the incubators early in March, but this is too early for this species. For some unknown reason one cannot get a normal percentage of hatch of the eggs

of *A. pomi* if they are brought into warm room temperatures earlier than 20 to 30 days before the outdoor hatching period. Even though the eggs failed to hatch, their rate of shrivel was most rapid in the dry air and air of low moisture content.

Besides the incubator experiments, several series of moisture experiments were conducted indoors and outdoors with the eggs of *A. avenæ* and *A. pomi* during 1919 and 1920. In each of these series approximately 2000 eggs were collected and divided into four groups (A, B, C and D) with 500 eggs in each. These were placed under four different conditions; two lots (A and B) were kept indoors (greenhouse or laboratory) in

TABLE I.

Incubator experiments showing the effect of variations in moisture on the hatch of the eggs of *A. avenæ* and *A. pomi*, 1917 and 1920. Constant temperature 80° F. 1917 and 70-72° F. 1920.

No.	Percentage of moisture	Chemical used to generate moisture	Percentage of hatch, <i>A. pomi</i> April 6, 17	Percentage of hatch, <i>A. pomi</i> March 20, 20	Percentage of hatch, <i>A. avenæ</i> March 25, 17
1	0-0.5	H ₂ SO ₄	2	0	4
2	25.9	CaCl ₂	0	12	12
3	45.7	Cu(NO ₃) ₂	—	18-20	—
4	56.1	NaBr	—	30	—
4	73.4	NaCl	20	43-45	20
6	80.0	NaNO ₃	—	55	—
7	100	H ₂ O	46	*	36
Average Number of eggs in each trial.....			100-125	500-600	25-50

* Killed by fungi.

a temperature of 60-75° F. Lot A was placed in a moist chamber which registered 90 per cent moisture or better, while lot B was exposed to the usual indoor moisture, which was somewhere between 35 to 50 per cent. The other lots (C and D) were placed outdoors; lot C in a moist chamber which registered 75 per cent moisture or better and lot D subjected to the natural outdoor environment during the two seasons.

Table 2 shows the results of these experiments. In each series the eggs in lots A and C, which were located in moist chambers, showed a greater percentage of hatch than the eggs in series B and D, which were exposed to the normal indoor or

outdoor environment. In other words, air of high moisture content, as in the moist chambers, is more favorable for hatching than the normal indoor or outdoor air having a lower moisture content.

In Table 2 it will be noted that the percentage of hatched eggs of *A. avenæ* brought into the laboratory on February 11, 1919, is very low. This experiment and others of a similar nature show that the eggs of this species usually will not give a normal percentage of hatch when they are brought into the laboratory too early in the season. In this respect

TABLE II.

Percentage of hatch of the eggs of *A. avenæ* and *A. pomi* under different temperatures and moisture conditions in 1919 and 1920, at New Brunswick, N. J. 500 eggs in each lot.

Series	Environment	<i>A. avenæ</i> Expt. started Feb. 11, 19	<i>A. avenæ</i> Expt. started Feb. 27, 19	<i>A. avenæ</i> Expt. started March 10, 20	<i>A. pomi</i> Expt. started March 9, 20
A	Indoors Moist chamber, 75-95% Temperature, 60-75° F.	7.6	66	50+	55
B	Indoors Average moisture, 35-50% Temperature, 60-75° F.	1.5	30	27	10
C	Out-of-doors Moist chamber, 75+ % Temperature variable	80	76	53	55
D	Out-of-doors Natural conditions Moisture and Temperature variable	67	56	38	29

they are somewhat similar to the eggs of *A. pomi*, which refuse to hatch if brought into a warm room earlier than 20-30 days before the normal outdoor hatching period.

In addition to the foregoing experiments on the response of the eggs to controlled moisture the author has made observations on the percentage of hatch of *A. avenæ* and *A. pomi* at New Brunswick for four seasons, 1917 to 1920. Table 4 gives observations for four seasons with the eggs of *A. avenæ*, showing the percentage of hatch and also the percentage of eggs with a split outer shell at the time hatching is rapidly taking place. The percentage of hatch varied considerably during the four years, yet these variations are probably due to the evaporation factors of the weather for the respective years. Unfortunately

no accurate record was made of the evaporating factors for each season, but if a comparison is made between the percentage of hatch and the rainfall for each year during the period when the eggs are most susceptible to moisture variations (10 to 14 days before hatching takes place rapidly) an interesting relationship exists. Table 3 shows the precipitation from March 5 to 31 for 1917 to 1920 and the H in each column indicates the date when rapid hatching occurred. In 1917 and

TABLE III.

Precipitation in inches for March 5-31, 1917, 1918, 1919 and 1920.

March	1917	1918	1919	1920
5	.09	.18	.07	1.17
6		.04		.71
7		.19	.26	
8	.50			
9	t	.02	.98	
10		.20	t	
11	.09			
12		.02	.10	.09
13				.98
14	.18	.84	.02	.03
15	.01	.03	.05	
16			.36	.07
17	.49		.06	.11
18	t		.22	
19				.12
20				.23
21	.17		H	
22				
23		H		
24	.42	.22		
25				
26				
27	.37	t	.55	t
28	.14	t	2.01	
29	t			.05H
30	H			
31	t			

t= trace of rain.

H=eggs started to hatch rapidly.

1919 it rained more than half of the fourteen days previous to hatching and 50 to 65 per cent of the eggs hatched, while in 1918 and 1920 it only rained three and five days out of fourteen, and 30 to 40 per cent of the eggs hatched.

It is a well known fact that evaporating factors are usually low during rainy and cloudy weather and high when the sun shines. Furthermore, we have learned from the moisture control experiments that low evaporation (high moisture content of air) produces a large percentage of hatch, while high evaporation (low moisture content of air) produces a low percentage of hatch. From these observations we may conclude that the

TABLE IV.

Relationship between the amount of rainfall (moisture index) 14 days before hatching and percentage of hatch and split shells of eggs of *A. avenæ* at New Brunswick, N. J.

	1917	1918	1919	1920
Percentage of hatch	50%	30%	60-65%	38-40%
Percentage with split shells at hatching period	?	45-50	35-40	40?
General description of moisture condition of weather 14 days before hatching	Wet	Dry	Very Wet	Dry
Days of rain in 14	8	3	13	5
Date when eggs started to hatch rapidly	3-30	3-23	3-21	3-29

weather conditions for the respective years influenced the percentage of hatch. In other words, wet weather during the ten to fourteen days previous to hatching permits a greater number of eggs to hatch than dry weather during the same period.

Evaporating factors also appear to determine the rate of split in the outside coating of the eggs. Comparing the rate of split in the outer coats for the two extremely different seasons of 1918 and 1919 it will be noted that in the dry season of 1918, 45 to 50 per cent of the eggs had split their outer coats at the time of hatching and only 30 per cent eventually hatched. In other words, 15 to 20 per cent or more of the eggs with split outer coats never hatched. During the wet season of 1919 the reverse was true, only 35 to 40 per cent of the eggs showed a split outer coat at the time of hatching and 50 to 65 per cent

eventually hatched. In other words, 30 per cent more hatched than had split their outer coats at the hatching period. This condition is quite opposite to that of 1918. The author is of the opinion that evaporating factors have a decided influence on the outer coat. Conditions producing high evaporation probably make the outer shell brittle and easily broken by the growing embryo within, while low evaporating conditions tend to make the outer shell elastic, thus permitting greater expansion before it breaks. If the above is true then an early rupture of the outer coat is apt to be detrimental, for it exposes the permeable membrane to evaporating factors for a long period of time, while a delayed rupture in the outer coat is beneficial since the inner pervious membrane is exposed to evaporating factors for only a short period of time. Briefly stated, the above observations show that an early split of the outer coat, which is usually followed by a low percentage of hatch, is probably brought about by the existence of high evaporation during the susceptible period, while a delayed splitting, which in turn may be followed by a high percentage of hatch, is probably brought about by the existence of low evaporating factors during the susceptible period.

From the above experiments and observations made on the percentage of hatch in variable seasons, the author concludes that variations in the moisture content of the air largely determines the percentage of hatch of fertile eggs and probably influences the rate of split in the outside coat of the eggs. In other words, the moisture content of the air influences the evaporation of the water content of the eggs, determines the percentage of hatch and probably influences the rate of split in the outside coat.

TEMPERATURE.

No extensive experiments were made to determine the influence of temperature (as a factor in evaporation) upon the percentage of hatch. A few observations were made in respect to the influence of temperature on the rapidity of the splitting of the outer layer and the hatching of the eggs. During the past season 500 eggs of *A. avenæ* were collected on March 6, 14, 20 and 24, from each of four orchards located near Bridgeton, Glassboro, Riverton and Cranbury (See Map, Fig. 5). These orchards are located in the southern half of the state

and they are named in order from south to north. Table 5 shows the percentage of hatch and the percentage of eggs with split outer coats on the respective dates. Eggs collected from the southern point, Bridgeton, showed a development decidedly in advance of the eggs collected from the northern point, Cranbury, in all of the collections, while eggs collected from Glassboro and Riverton were intermediate in their stage of development. It is of interest to note that the stage of development in collections from the last named places were approximately the

TABLE V.

Influence of the geographical position (temperature) on the development of the eggs of *A. avenæ*. The percentage of eggs with a split outer shell and the percentage hatched in collections made on March 6, 14, 20 and 24, 1919, from four orchards (See Map) in the southern half of New Jersey.

Collected Observed	Per-centage Split	Per-centage Hatched	Per-centage Split	Per-centage Hatched	Per-centage Split	Per-centage Hatched	Per-centage Split	Per-centage Hatched
March 6	13	0.2 h	12.3	0.0 h	16	0.5 h	8.3	0.0 h
March 14	26	6 h	17	1 h	26	2 h	14	0.4 h
March 20	14	45 h	30	22 h	26	25 h	35	3.4 h
March 24	0.0	60 h	5	64 h	2	65 h	10	55 h
Location of Orchard	Bridgeton		Glassboro		Riverton		Cranbury	
Feet (approximate) above sea level	40		150		25		120	

h = Hatched eggs.

same. One would expect collections from Riverton to show a slower stage of development. Probably the location of the orchard has something to do with this. The orchard at Glassboro is approximately 100 ft. higher than the orchard at Riverton; furthermore the orchard at Riverton is within one mile of the Delaware river and the river at this point is subject to tide.

Low temperature may kill a small percentage of eggs. The dormant season of 1917-1918 was exceptionally cold, while the winter of 1918-1919 was mild and the temperature never went below 0° F. Eggs of *A. avenæ* brought into the laboratory during the last week in February of 1918 and placed in moist chambers (75-90 per cent moisture; room temperature 70° F.) showed 43-47 per cent hatch, while a similar experiment in 1919 showed 60-66 per cent hatch. This difference in

percentage of hatch might be accounted for by the low temperature of 1918; however, it is impossible to make a definite statement regarding this matter because the evaporating factors previous to the time when the eggs were brought into the laboratory may have been very different for the two seasons and this may have influenced the percentage of hatch. In other words it is possible that evaporating factors may have been much greater during the cold, dry season of 1917-1918 than during the mild wet winter of 1918-1919. This might account for the difference in the percentage of hatch in these experiments which were conducted under similar conditions during the respective season.

REFERENCES BY AUTHOR.

1917. Studies on the Morphology and Susceptibility of the Eggs of *Aphis avenæ* Fab., *Aphis pomi* DeG. and *Aphis sorbi* Kalt. Jour. of Econ. Ent., Vol. 10, pages 556-560.
1918. Some Studies on the Eggs of Important Apple Plant Lice. New Jersey Agric. Expt. Sta., Bull. 332.
1919. Response of the Eggs of *Aphis avenæ* Fab. and *Aphis pomi* DeG. to Various Sprays, Particularly Concentrated Lime-sulfur and Substitutes, Season 1918-1919. Journ. Econ. Ent., Vol. 12, pages 363-386.

EXPLANATION OF PLATE XXXI.

All Figures of the eggs are typical of *Aphis avenæ* and *Aphis pomi*.

- Fig. 1. Dorsal view of a normal dormant egg.
- Fig. 2. Dorsal view of an egg showing an early stage in the usual type of splitting of the outer semi-transparent layer.
- Fig. 3. Dorsal view of an egg showing an advanced stage in the usual type of splitting of the outer semi-transparent layer.
- Fig. 4. Dorsal view of an egg showing an early stage in the emergence of the nymph. Note the egg burster on the head of the nymph along the meson and the cut pigmented inner layer.
- Fig. 5. Map of New Jersey, showing location of orchards where eggs were collected for experiments recorded in Table 5.
- Fig. 6. Diagrammatic drawing of a moisture control equipment.

ABBREVIATIONS.

- b. = Egg burster.
n. = Nymph.
p. = Inner pigmented layer (chorion).
t. = Outer semi-transparent layer.